



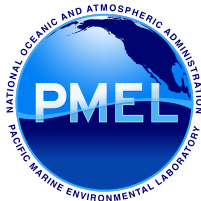
PMEL

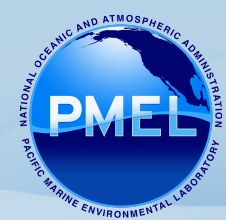
Pacific Marine Environmental Laboratory

Climate Research

Large-Scale Ocean Physics

Gregory C. Johnson





Program Elements & Personnel:

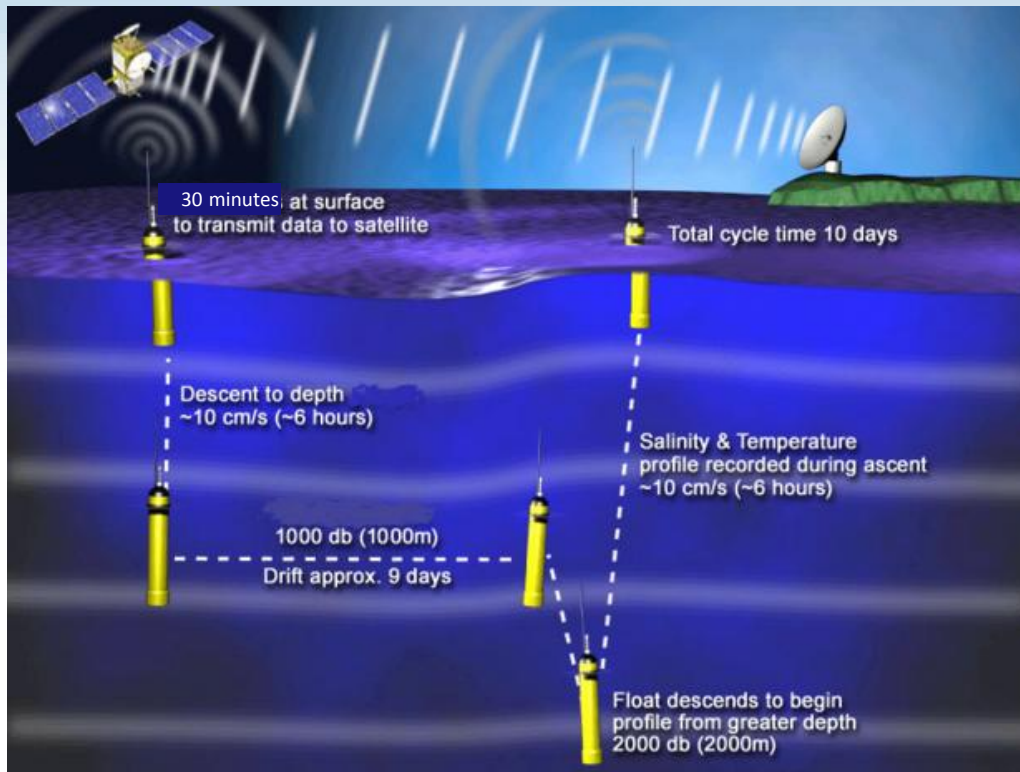
Background

- Global Ocean Measurements & Analyses:
 - Argo
 - Repeat Hydrography & West Coast OA cruise CTD/O₂ support
 - Analyses, Reports, & Assessments
 - Deep Argo
- Personnel
 - Dr. Gregory Johnson (PI)
 - Ms. Kristene McTaggart (Oceanographer)
 - Dr. Elizabeth Steffen (JIMAR: Float Research Analyst)
 - Dr. John Lyman (JIMAR: Assistant Researcher)
 - Ms. Paige Logan (UW: Graduate Research Assistant, 2014–present)

 - Dr. Sarah Purkey (UW: Graduate Research Assistant, 2008–2014)
 - Dr. Marion Meinville (NRC: Postdoctoral Fellow, 2012–2013)
 - Dr. Sunke Schmidtko (NRC: Postdoctoral Fellow: 2009–2011).

What is an Argo Float?

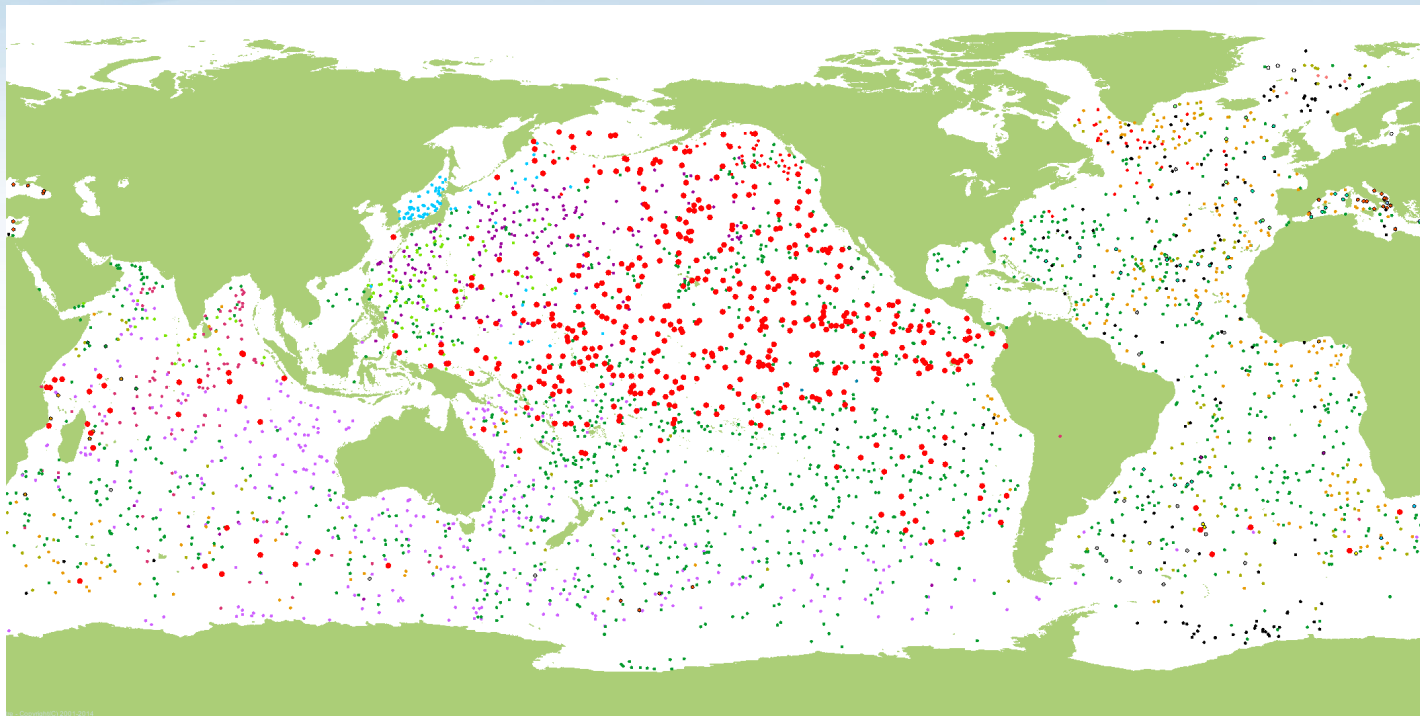
Background: (<http://floats.pmel.noaa.gov>)



Argo at PMEL

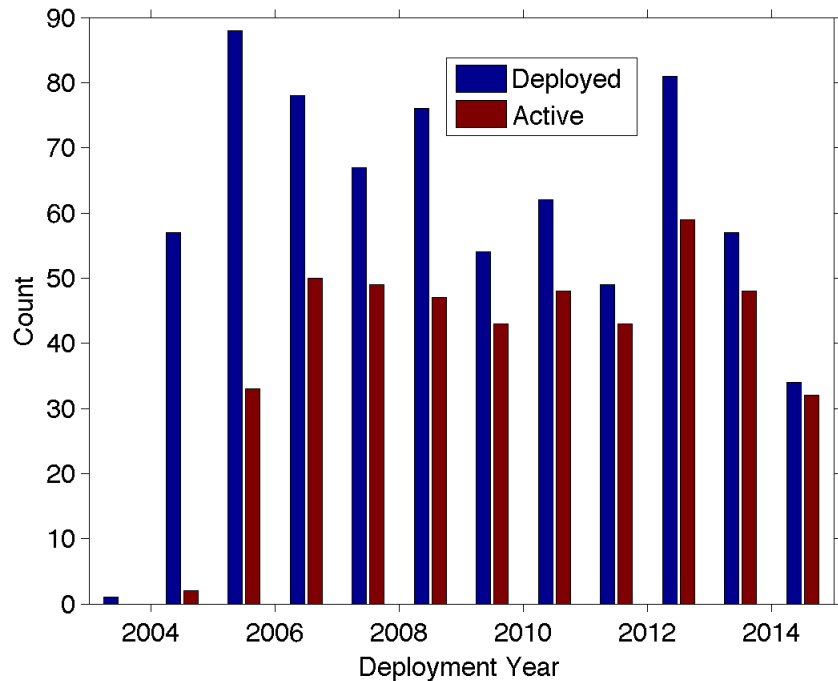


Quality & Performance: (<http://floats.pmel.noaa.gov>)



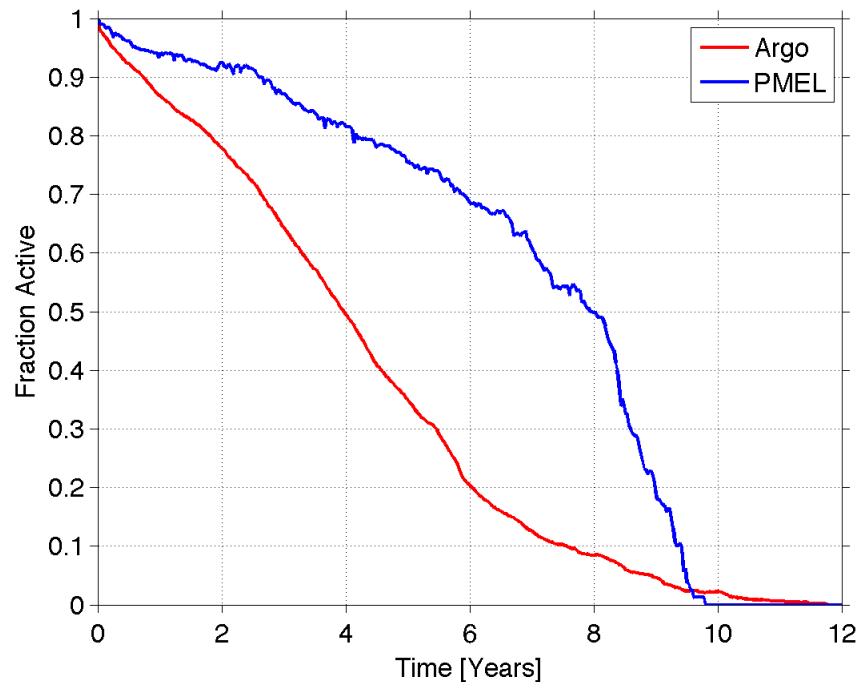
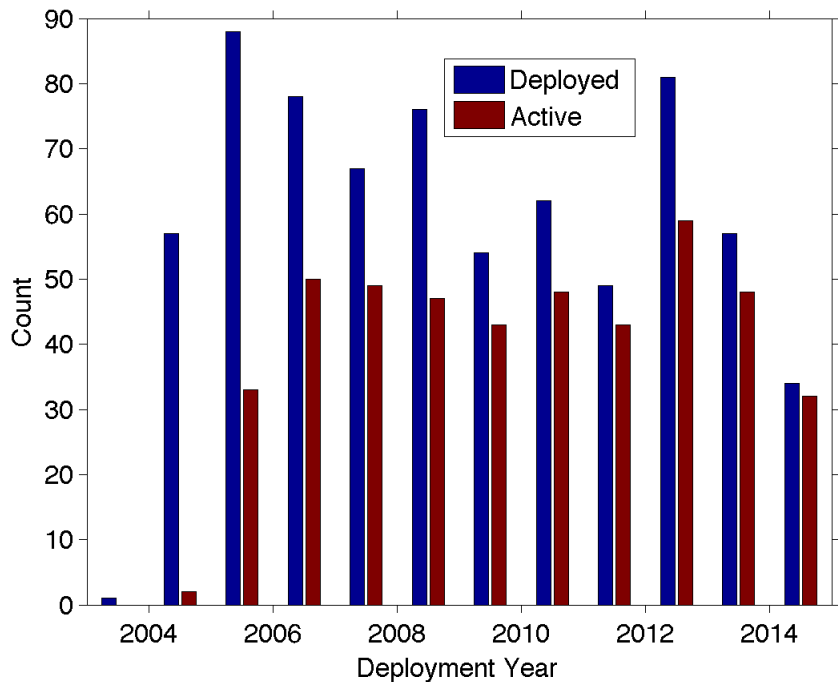
- International global, year-round obs. with **PMEL** & **other US** floats
- Commenced in 2000, 3000-floats by November 2007, now > 3600 active floats
- Enhanced coverage: Marginal Seas, Eq. Pacific, WBCEs, Ice zones
- Over 100,000 high-quality profiles per year, nominally to 2000 m

Argo at PMEL: Float Providing Quality & Performance



- Funding roughly flat since 2003, inflation offset by efficiency increases . . .
- Half of PMEL floats deployed 8+ years ago active for 8 years!
- Started deploying Iridium/GPS APEX floats in 2010, Navis in 2012.
- Careful testing, repair, performance evaluation improves performance
- Found numerous problems in APEX and now Navis floats.

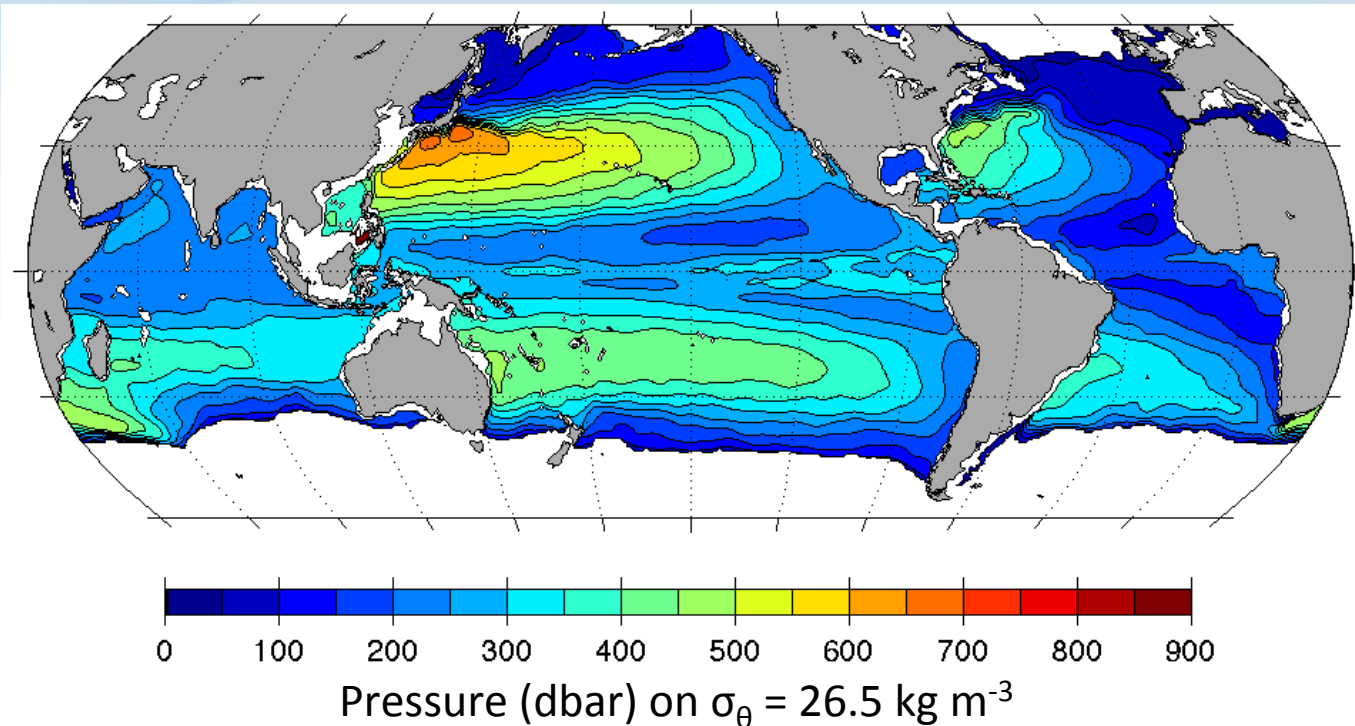
Argo at PMEL: Float Providing Quality & Performance



- PMEL floats have lived 6.7 years on average vs. 4.1 for Argo as a whole

Argo at PMEL: Analyses

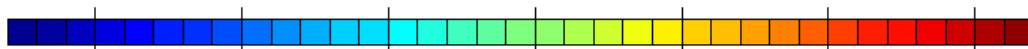
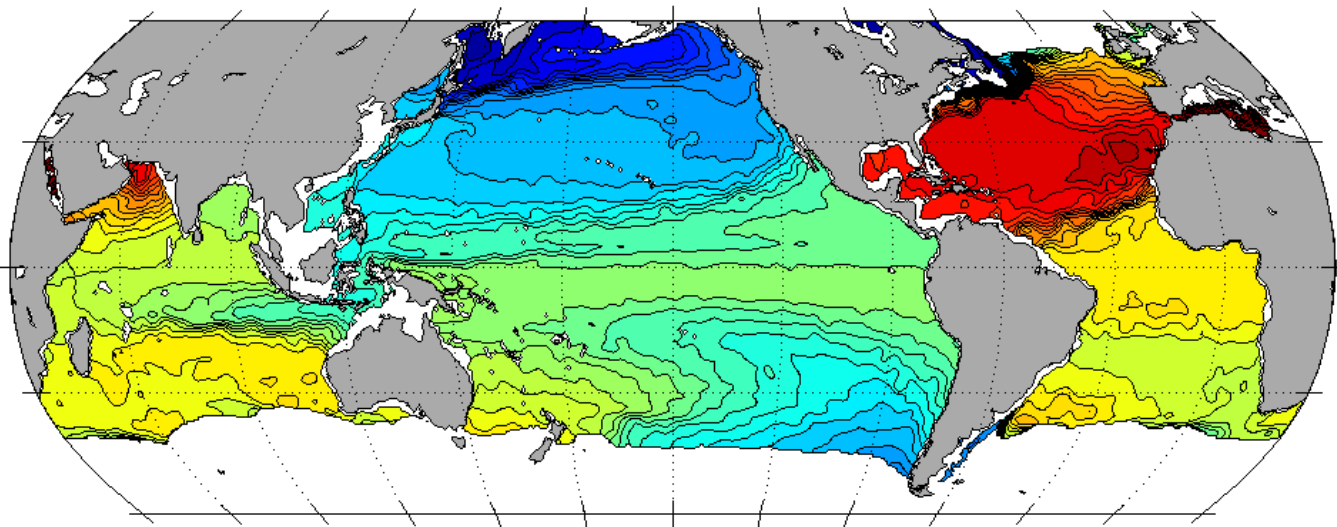
Quality & Relevance



- Monthly Isopycnal Mixed-layer Ocean Climatology (MIMOC; Schmidtko et al., 2013)
- Pressure on isopycnals is a dynamical parameter, reflects gyre circulation.

Argo at PMEL: Analyses

Quality & Relevance



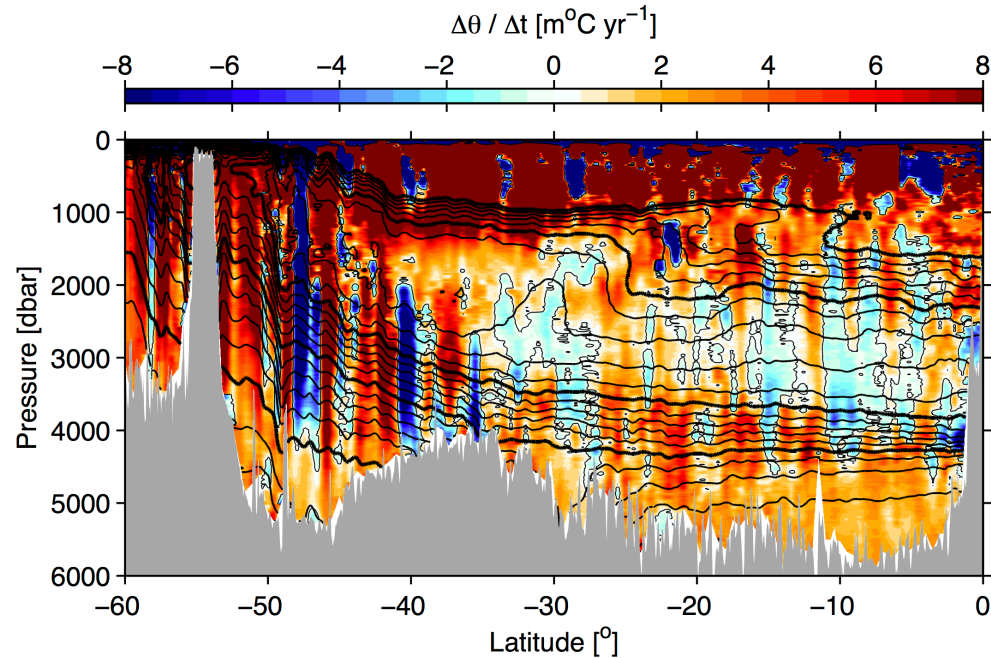
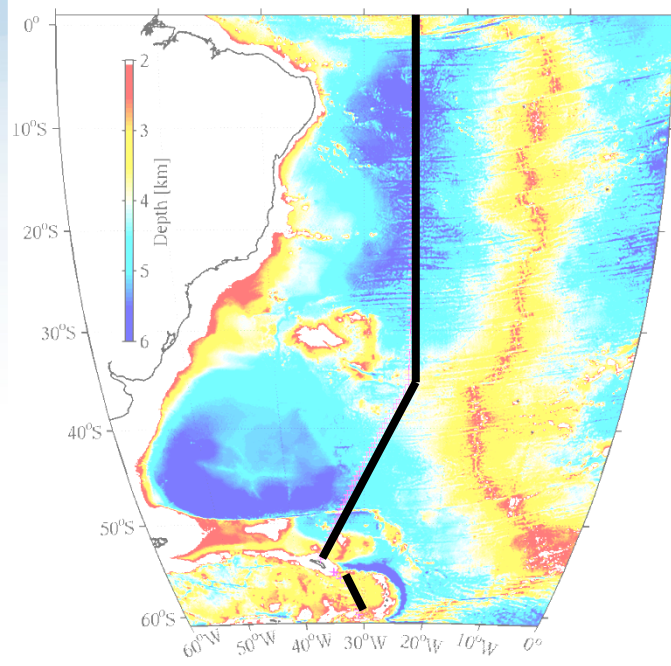
34 34.5 35 35.5 36 36.5 37

Absolute Salinity (g kg^{-1}) on $\sigma_{\theta} = 26.5 \text{ kg m}^{-3}$

- Salinity on isopyncals is a water-mass tracer, reflects inter-gyre and inter-basin exchanges.
- Argo float data allow analyses of mean ocean, seasonal cycle, variability, long-term changes (coupled with historical data).

Repeat Hydrography:

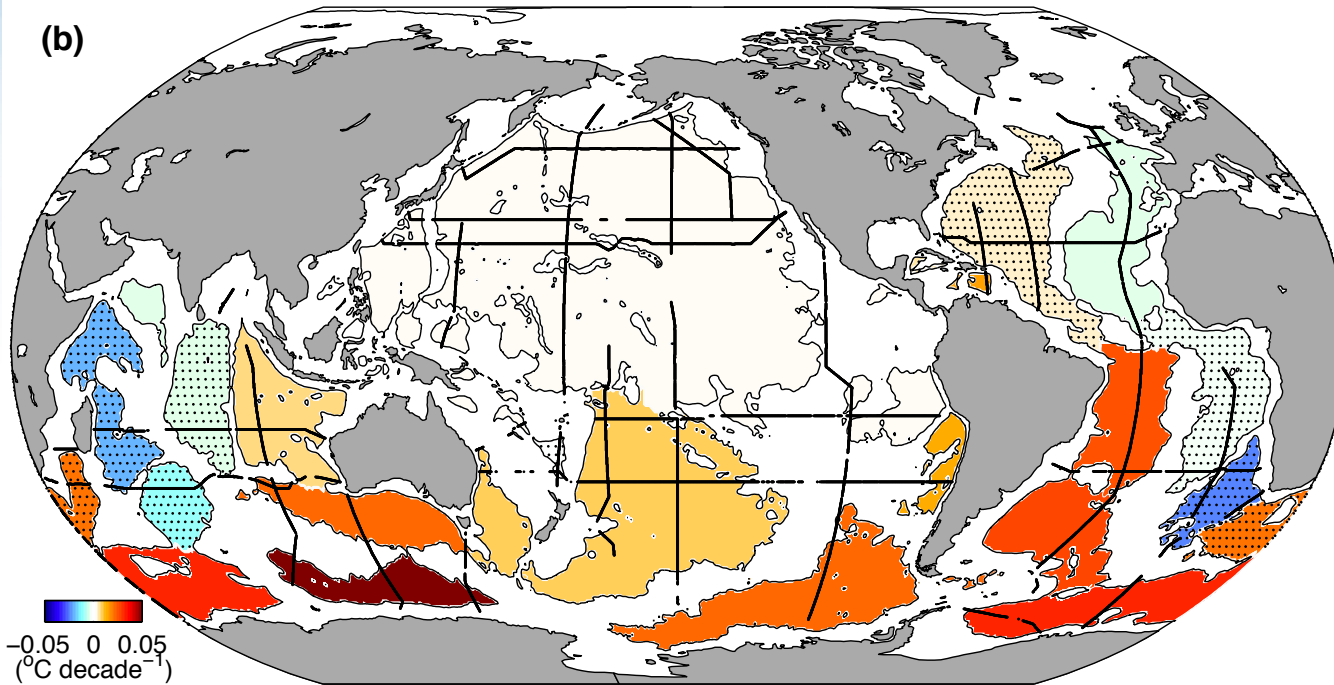
Quality & Relevance: Warming 1989–2014.



- Temperature trends from data in 1989, 2005, and 2014 (colors) with mean isotherms (black)
- Antarctic Bottom Water warming at about 0.03°C per decade throughout western S. Atlantic

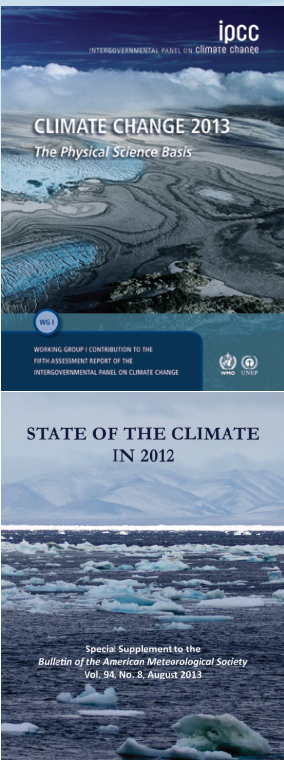
Repeat Hydrography

Quality & Relevance: Abyssal Warming

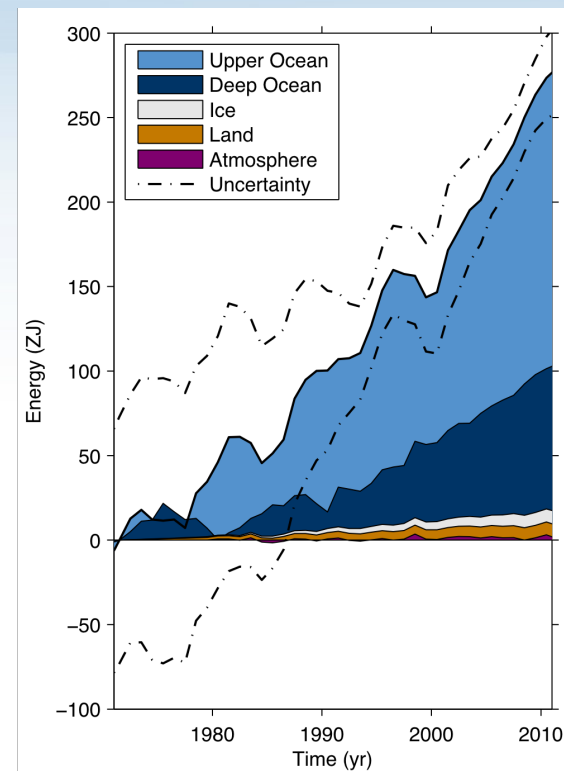


- Data through 2010 reveal warming of AABW, contributes 0.07 W m^{-2} in global heat gain & 0.11 mm yr^{-1} global sea level rise below 2000 m
- AABW ($\theta < 0^{\circ}\text{C}$) shrinking at 8.3 Sv (10 m descent per year)
- AABW also freshening at around 73 Gigatons per year (compare to ice sheet melt)
- Purkey and Johnson (2010, 2012, and 2013)

Large-Scale Ocean Physics: Quality, Relevance, & Performance



- **IPCC:** Lead Author, Chapter 3, Observations: Ocean
- Contributing Author: Ch. 9 (Models Evaluation); Ch. 13 (Sea Level); Technical Summary; & Summary for Policymakers
- Ch. 3 Contributing Authors: Sarah Purkey & Sunke Schmidtke
- **SoC Reports:** Johnson & Lyman lead Ocean Heat Content since 2006 and Sea-Surface Salinity sections since 2007
- Sidebars on: 1. Advances in ocean heat content understanding, 2. Aquarius Satellite data, & 3. Reductions of the southern MOC
- **Example:** Ocean warming ~93% of observed increases in global thermal energy storage.
- Warming ~16% abyssal ($z > 2000$ m)





Large-Scale Ocean Physics:

Quality & Performance: By the numbers since Sept. 2008

DATA

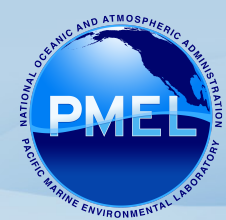
- **4 Repeat Hydrography cruise CTD/O₂ data sets (A13.5, A10, A16N, & A16S)**
- **3 West Coast OA cruise CTD/O₂ data sets (2011, 2012, & 2013)**
- **~86,000 Argo profiles collected from ~660 Argo floats. Pioneered salinity QC procedures.**

RESEARCH & ASSESSMENTS

- 37 articles on a variety of topics in refereed scientific journals
- 15 sections and 3 sidebars in 7 Annual State of the Climate Reports
- 8 papers for OceanObs09
- 2 books (including IPCC WG1 AR5)
- 2 chapters for GO-SHIP Repeat Hydrography Manual

STUDENTS & POSTDOCS

- 1 Ph.D. graduated & 1 starting
- 2 postdoctoral scholars advised



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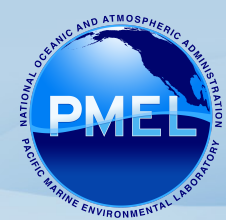
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Large-Scale Ocean Physics:

Relevance: NOAA R&D 2013–2018 Plan

- Climate Adaptation & Mitigation

- Key Question:** What is the state of the climate system and how is it evolving?

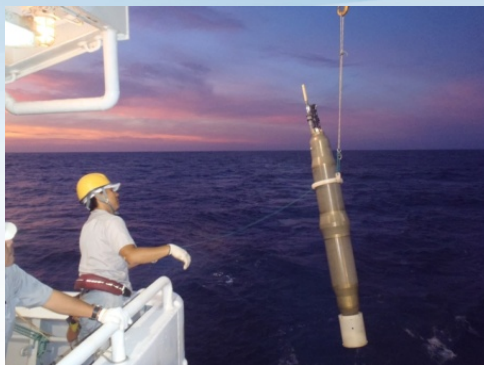
- **Objective 1:** Sustained Climate Record

- NOAA will continue to provide the Nation and the world with an unambiguous measure of the state of the climate through uninterrupted, high quality *in situ* and remotely-sensed observations of primary variables describing the ocean, atmosphere, and other components of the climate system.

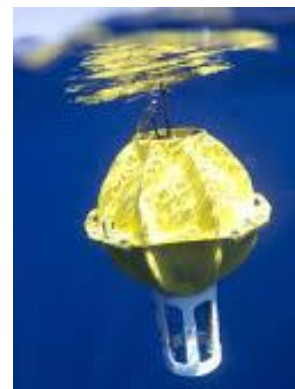
- **R&D Targets:**

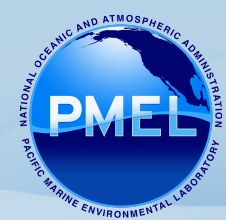
- Advance research on technological solutions for climate observations and the data they produce to improve the lifecycle, timeliness, and accuracy of these observations
 - Assess collected climate data for quality, uncertainty, and the implications for impacts; make data and subsequent products available to users
 - Develop and test improved climate observing systems in the deep ocean

Future Directions: Deep Argo



- International effort with 4000-m NINJA (upper right) and Arvor (upper left) floats.
- US 6000-m float Pilot Program through PMEL with SIO & UW focusing first on SW Pacific:
- Deep APEX (lower right): Prototype successfully tested to 6000 m
- Deep SOLO (lower left): Two deployed during June 2014 cruise off NZ with profiles compared to shipboard CTD data
- Profiling to 5500 m off NZ every 3.5 days to evaluate performance & variability, to be recovered next year when about 10 more are deployed.





Summary

- Argo is continuing to evolve, still active research (Iridium floats, under ice, Deep Argo)
- Even with Deep Argo Repeat Hydrography will be needed for:
 - Traceable calibration standards for Temp & Salinity
 - High-quality oxygen, nutrient, carbon, transient tracer, and other data
 - Coast-to-coast full depth synoptic sections for transport estimates
- End-to-end work: Hardware, data quality control standards, research, & assessments
- Group science results:
 - Upper ocean heat content assessments (with Lyman)
 - Antarctic Bottom Water warming, contraction, & freshening (with Purkey)
 - Global analyses of water-properties, currents, ocean mass (e.g., Youngs)